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DETERMINATION OF HANDLING QUALITIES AND DISPLAY REQUIREMENTS FOR HELICOPTER INSTRUMENT FLIGHT DURING DECELERATING APPROACHES TO SLOW SPEEDS

by
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National Aeronautical Establishment

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DETERMINATION OF HANDLING QUALITIES AND DISPLAY REQUIREMENTS FOR HELICOPTER INSTRUMENT FLIGHT DURING DECELERATING APPROACHES TO SLOW SPEEDS

DÉTERMINATION DES EXIGENCES EN MATIÈRE DE QUALITÉS DE MANOEUVRABILITÉ ET D'AFFICHAGE POUR LE VOL AUX INSTRUMENTS DES HÉLICOPTÈRES PENDANT LES APPROCHES EN DÉCÉLÉRATION À DE FAIBLES VITESSES

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Laboratoire de recherche en vol

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SUMMARY

This paper discusses the most recent phase of a series of experiments performed jointly by the National Aeronautical Establishment and the United States Federal Aviation Administration under Memorandum of Agreement AIA-CA-31. The experiment was aimed at determining the helicopter instrument flight handling qualities requirements when performing steep approaches to low decision heights to a landing area colocated with a Microwave Landing System (MLS).

A total of 118 approaches were evaluated by three helicopter certification test pilots and one operational/training helicopter pilot. Results indicate that with simple rate damping augmentation in pitch, roll and yaw, and flight director guidance, a Bell 205A-1 exhibited borderline Level 1 (certifiable) handling qualities when performing decelerating approaches to 20 knots to decision heights representative of Category IIIA weather limits.

RÉSUMÉ

Le présent document traite de la plus récente phase d'une série d'expériences réalisées conjointement par l'Établissement aéronautique national et la Federal Aviation Administration des États-Unis en vertu du protocole d'entente AIA-CA-31. L'expérience visait à déterminer les qualités de manoeuvrabilité requises d'un hélicoptère effectuant, en conditions de vol aux instruments, une approche à forte pente à de basses hauteurs de décision vers une aire d'atterrissage avec un système d'atterrissage à micro-ondes (MLS).

Au total, 118 approches ont été évaluées par trois pilotes d'essai de certification d'hélicoptères et un pilote d'hélicoptères d'exploitation/entraînement. Les résultats montrent qu'avec une simple augmentation de l'amortissement en tagage, en roulis et en lacet, et sous la gouverne du directeur de vol, un Bell 205A-1 présente des qualités de manoeuvrabilité de niveau 1 limite (certifiable) lorsqu'il effectue des approches en décélération à 20 noeuds à des hauteurs de décision représentatives des limites météorologiques de la catégorie IIIA.

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DETERMINATION OF HANDLING QUALITIES AND DISPLAY REQUIREMENTS FOR HELICOPTER INSTRUMENT FLIGHT DURING DECELERATING APPROACHES TO SLOW SPEEDS

1.0 BACKGROUND

In recent years, there has been a departure in helicopter instrument flight handling qualities requirements from the long evolution of requirements for fixed wing aircraft. Special emphasis is being placed on using the unique capabilities of helicopters to a greater extent, brought on mainly by pressures to operate in areas where availability of real estate is severely restricted. The incorporation of Microwave Landing Systems (MLS) into heliport operations has served as a catalyst in allowing helicopters to exploit their unique capabilities under instrument weather conditions.

Helicopter handling qualities have inhibited the full realization of helicopter capabilities. Typically, helicopters have been limited in IFR operations down to a minimum IFR speed (V_{mini}) of 50 to 60 knots. The requirement for a visual deceleration from this speed constrains operations to a decision height such that sufficient range to the heliport is available for the deceleration. This problem is further compounded by real estate constraints that require MLS transmitters to be colocated with the helipad.

On 12 June 1986 the United States Federal Aviation Administration (FAA) issued a Notice of Proposed Rule Making (NPRM) Notice No. 86-7 proposing to amend helicopter instrument flight airworthiness requirements for the

approach and landing phases. Permission would be granted for instrument flight at airspeeds below V_{mini} with the aid of a 3 cue flight director. Furthermore, recently the FAA has certificated one aircraft with a V_{mini} of 60 knots to approach speeds of 40 knots without a flight director.

2.0 INTRODUCTION

The Flight Research Laboratory (FRL) of the National Aeronautical Establishment (NAE) has been actively engaged in joint programs with the FAA aimed at investigating the acceptability of helicopter IFR handling qualities. Under the most recent Memorandum of Agreement AIA-CA-31, with joint funding, the NAE and FAA completed a phase in a series of experiments to address the improvement of helicopter IFR handling qualities required to allow approaches to low decision heights (50 feet) to a landing area colocated with an MLS glideslope and azimuth transmitter. This paper discusses this most recent phase of the experiment.

3.0 SCOPE OF THE PROGRAM

This phase of the experiment was designed to limit investigations to approaches to Category II (100 feet ceiling, 1/4 mile visibility) minima at constant speed, and Category IIIA (0 feet ceiling, 700 feet visibility) minima in a decelerated approach. It is evident that operations below the above specified minima would require a significant increase in display sophistication, to be addressed in later programs.

4.0 THE AIRBORNE SIMULATOR

The NAE Airborne Simulator is an extensively modified Bell 205A-1 helicopter with capabilities that have evolved over the last decade (Fig. 1 and 2). Basically, the standard hydraulically boosted mechanical control actuators have been replaced by dual-mode electro-hydraulic actuators. The actuator valves can be positioned mechanically from the left (safety pilot) seat or electrically from the right (evaluator pilot) seat full authority fly-by-wire station. Electrical controllers can be either conventional stick, pedals and collective with a programmable force-feel system or 4-axis isometric force or deflection side-stick controllers. For this program, conventional controllers and the electro-mechanical servo valves were integrated with a variable force-feel system, a hybrid computing system and a set of motion sensors. The computing system consisted of three LSI 11/23 microprocessors, and D/A and A/D converters.

In order to improve the control responses of the teetering rotor system, the stabilizer bar has been removed. For this program, the longitudinal cyclic-to-elevator link, normally replaced with an electro-hydraulic actuator, was removed and the elevator was fixed in the neutral position.

In order to simulate instrument flight conditions visually, an IMC Simulator manufactured by Instrument Flight Research Incorporated, Columbia, S.C. was employed. Goggles, worn by the evaluation pilot, had lenses which incorporated liquid crystals to vary the desired goggle opacity. For this program, a narrow field of view was maintained unobscured with the remaining peripheral view highly obscured. When descending through the decision

height as selected by the evaluator on the radio altimeter, the peripheral view of the goggles could clear automatically to a simulated visibility of three miles. The safety pilot could inhibit the clearing of the goggles at decision height by activating a switch on his collective control when breakout to visual conditions was not desired.

4.1 Cockpit Display

On all approaches, primary approach information was displayed in a consolidated form on a Litton Multi-Mode Matrix (MMM) display shown in Figure 3. The 5 inch by 5 inch display consisted of light emitting diodes organized in matrix form with a density of 64 pixels per inch. In this program, this display was used to represent a modern "state-of-the-art" display which could be changed readily to provide three levels of display sophistication, namely, raw situation flight data, a two-cue flight director and a three-cue flight director. In the raw data display the roll, pitch and collective flight director symbols were not provided. The collective flight director symbol was omitted in the two-cue flight director display. When on a flight directed decelerating approach, the pitch and roll flight director symbol flashed a 350 feet radio height to warn the pilot of the approaching deceleration command and returned to the steady symbol once the deceleration was started.

On all approaches, the radio height box on the left of the display and the digits within the box flashed at 10 feet above decision height and remained flashing while below this height. An additional warning of decision height was provided in the form of an audio tone which came on at 10 feet above decision height and went off at decision height.

4.2 Flight Director

As mentioned previously, three display configurations were evaluated: raw situation data indicating azimuth, glideslope and speed deviations; a two-cue flight director with speed tracking performed by controlling pitch attitude, and azimuth tracking with bank angle; and a three-cue flight director where a collective cue was added to the two-cue display for tracking glideslope. A thorough discussion of the flight director control laws can be found in Reference 2.

With the raw situation display, the pilots merely nulled positional errors in glideslope and azimuth by using the collective control and aircraft heading respectively. Display gain for glideslope was set at $\pm 2°$ full scale and $\pm 6°$ full scale for localizer. At 200 feet and below, azimuth and glideslope deviations represented linear deviations from the desired flight path. Pitch attitude changes were used to control speed as presented as a speed error signal (fast/slow) on the speed display on the right hand side of the Multi-Mode Matrix display.

With the two-cue flight director selected, the pilot tracked speed and azimuth by flying the aircraft symbol towards the square dot flight director symbol. A block diagram representing the pitch flight director control laws is included in Figure 4. The pilot could select either a reference speed for constant speed approaches or the speed deceleration profile by selecting Switch 1. Normally, Doppler groundspeed was used by selecting Switch 2, but when approach tailwinds exceeded 10 knots this switch was selected to provide pitot static airspeed for either a

constant speed approach or a deceleration. The speed error signal, obtained as the difference between the reference or the deceleration profile as selected and the aircraft forward speed, was then fed through a proportional path and an integral path. The integral path was included as a means of eliminating steady-state error in longitudinal speed. On decelerating approaches, Switch 3 was activated automatically at 300 feet to provide an open-loop 10 degree pitchup command, diluted by washout and low-pass filters. Selection of Switch 4 on the pilot's cyclic controller provided a go-around mode, which when activated provided a nose down pitch command of -5° for overshoot. Washed-out pitch attitude feedback helped eliminate steady-state velocity errors in the cruise, and longitudinal acceleration feedback provided damping for the pitch attitude command signal.

A block diagram representing the roll attitude flight director control laws is included in Figure 5. The gain of the localizer error was scheduled with range from the transmitter to 20% of full value below an altitude of 300 feet. An integrator (c in Figure 5) prevented steady state errors in localizer. Feedback quantities of heading rate and roll rate were used to dampen the resulting command signal.

When the evaluator selected a three-cue flight director, a collective command symbol was provided to the pilot in addition to the previously discussed two-cues. A block diagram representing the collective flight director control laws is shown in Figure 6. Glideslope capture occurred once the error was less than $\pm$0.25 degrees. Aircraft forward speed was converted to a reference vertical

speed for a particular glideslope (6 degrees). This value was compared with vertical speed to provide a vertical speed error signal. As shown on the bottom branch of Figure 6, the glideslope error and vertical speed error provided the flight director input for collective control. When at decision height, the collective flight director provided a level off command by maintaining its height reference at the decision height setting.

4.3 Speed Presentation

As mentioned previously, the evaluator could select either groundspeed (as derived from the Doppler) or airspeed for approach. Airspeed was obtained from dynamic pressure provided from two wide angle pitot tubes located on two 10 inch booms on the nose of the aircraft. The static pressure source, which could swivel into the relative airflow, was located on a six foot boom on the nose of the aircraft. High frequency airspeed excursions were smoothed with longitudinal inertial velocity to give smooth, accurate airspeed indications down to 15 knots. Groundspeed was used as the approach parameter except when tailwinds exceeding 10 knots were present. In those cases airspeed was used.

On constant speed approaches (40 knots), the reference speed was selected by the evaluator. Nulling the speed error provided this speed throughout the approach.

On decelerating approaches, the evaluator selected 60 knots as reference speed. The speed error signal was referenced to this speed down to 300 feet approach height, below which the speed deceleration profile shown in Figure 7 was automatically incorporated as the speed reference

signal. When using the flight director in the deceleration mode the speed signal commanded 20 knots at or below the 50 foot decision height. When below decision height, the speed reference was maintained at 20 knots, giving the pilot a level off command in preparation for a go-around manoeuvre.

5.0 GROUND AIDS

Two Co-Scan, fixed azimuth, variable glideslope transmitters were located back-to-back, one providing azimuth and glideslope information for approach, and the second one used only for back-course guidance on overshoot. A simulated but unmarked landing pad was located adjacent to the MLS transmitters.

6.0 AIRCRAFT CONTROL CONFIGURATIONS

For this experiment, one basic helicopter control configuration was maintained with workload relief features added to it. The basic configuration, as shown in the schematics in Figure 8 retained all Bell 205A basic characteristics but with rate damping augmentation in pitch, roll and yaw. Rate feedback in each of the three rotational degrees of freedom increased the rate damping by approximately 100%. The following workload relief features were added to the basic control configuration:

6.1 Pitch and Roll Attitude Retention

A "soft" attitude stabilization was incorporated in pitch and roll. Attitude feedback was provided at a low level, allowing attitude retention under steady state flight conditions but yet was of a low enough gain to allow the

pilot to perform short term attitude changes. Changes in the pitch or roll reference attitude could be performed by disengaging attitude hold (depressing a button on the cyclic control) and re-engaging at the new attitude, or by using the electric trim button (coolie hat) on the cyclic control and retrimming to the new attitude.

6.2 Sideslip Suppression

On some approaches, the pilot could select a sideslip washout feature which provided turn coordination and sideslip suppression. This feature was scheduled to automatically washout as speed decreased below 40 knots, to be completely cancelled by 25 knots.

6.3 Heading Hold

Pilots also evaluated a heading hold feature, where the pilot would stabilize on a heading, select heading hold, and track the azimuth flight director using lateral cyclic. Errors in azimuth were corrected by sideslipping towards the azimuth beam. The reference heading could be changed by applying a minimum of 1-1/2 pounds differential force on the tail rotor pedals. With heading hold engaged it was imperative that the pilot keep his feet off the pedals unless a heading change was required.

7.0 EXPERIMENTAL PROCEDURES

Approximately 4 hours flight training time was provided for each evaluator to become familiar with the task, the display and the control configurations. During the evaluations, the particular configuration flown on each approach was known to the pilot.

The basic task was to perform a 6 degree MLS approach to a simulated heliport with a colocated MLS transmitter to a decision height of 50 feet and then land or overshoot as dictated by the simulated weather conditions. Figure 9 is an example of the approach plates supplied to the evaluator.

The pilot was required to intercept the MLS localizer at 2000 feet MSL, decelerate to 60 knots, and intercept and track the 6 degree glideslope. At 3500 feet range, the square dot at the centre of the aircraft symbol on the MMM (pitch and roll flight director when used as such) flashed to provide warning of the deceleration manoeuvre which commenced at 3000 feet range. When on raw data, the pilot nulled the speed error cue on the right of the MMM display with pitch attitude. When using flight director, the pilot followed the pitch and roll attitude as provided by the square dot symbol on the MMM display. Localizer, glideslope and speed were tracked to a decision height of 50 feet. At 60 feet, two warnings of decision height were provided, an audio tone and a flashing of the radio attitude digit box, which both terminated below 50 feet. On reaching decision height, the pilot was required to land visually or to perform a missed approach as dictated by the simulated weather situation.

The evaluators completed the questionnaire in Figure 10 for each approach. Each questionnaire required the evaluator to submit a Cooper/Harper handling qualities rating (Figure 11(a)) and a Certification-Related Assessment (Figure 11(b)).

Each pilot flew approximately 5 hours of evaluation flying. A total of 118 approaches were evaluated. Four test pilots participated in the evaluations, two helicopter certification test pilots from the FAA, one certification test pilot from Transport Canada, and one operational/training pilot from the FAA. A list of relevant pilot experience is shown in Figure 12.

7.1 Weather Conditions During the Evaluations

A variety of winds and turbulence conditions were experienced during the evaluations; including a 10 knot head wind in smooth conditions, tailwinds of up to 15 knots at ground level with windshear aloft, to conditions of a beam wind gusting from 15 to 20 knots with moderate turbulence and significant windshear. When tailwinds in excess of 10 knots were experienced on approach the evaluators tracked airspeed rather than groundspeed.

8.0 SUBJECTIVE ASSESSMENTS OF THE APPROACH

8.1 Handling Qualities Ratings

Handling qualities subjective assessments in terms of Cooper/Harper ratings are summarized in Figure 13. The dots in each case represent a numerical average of the ratings and the vertical lines represent the spread of ratings provided. Figure 13(a) includes all approaches flown without attitude stabilization for the three display configurations. Solid lines indicate decelerating approaches and dotted lines indicate constant speed approaches.

The contribution of flight directed displays to handling qualities improvement is readily apparent, especially when performing decelerating approaches. Ratings went from borderline Level 2 where adequate performance required extensive pilot compensation with raw data to borderline Level 1 where desired performance required minimal to moderate compensation with either a two-cue or three-cue flight director. It is interesting to note that the constant speed approaches were rated similar to the decelerating approaches when the flight director was used. Figures 13(b) and 13(c) are plots separating out approaches performed in smooth conditions and in moderate wind shear, crosswind and turbulence. With raw data only, a pronounced degradation in handling qualities was apparent in rough atmospheric conditions, a factor not apparent when flight director was used. Decelerating approaches were rated similar to the constant speed approaches.

Throughout the program, no conclusive preference was shown for the control configurations with attitude stabilization. Pilots' comments tended to indicate a preference for the automatic turn coordination but this was not apparent from the rating scales. Any workload relief provided by the heading hold configuration was also inconclusive. The presence of significant wind shear resulted in uncomfortable sideslip angles when heading hold was engaged.

8.2 Certification Assessment

Data from the Certification Assessment Forms in Figure 14 is consolidated in two plots. Where a marginal single pilot rating was provided this was plotted between the

single pilot (1P) and two pilot (2P) ratings. The most obvious conclusion that may be drawn from these data is that all approaches where flight director was used resulted in certifiable assessments. On the other hand, a significant number of approaches with raw data alone were rated uncertifiable, especially those performed in conditions of windshear and turbulence. When using the raw data display, the pilots experienced a slightly lower work load level during constant speed approaches as evidenced by a lower proportion of approaches rated uncertifiable while maintaining constant speed than during decelerations but usually only during smooth air conditions.

9.0 TRACKING ACCURACY

Figure 15 shows the tracking accuracy obtained during the approaches. As explained earlier, decelerations were started at approximately 3000 feet range (300 feet AGL) and the instrument approach was terminated at 500 feet range (50 feet AGL).

Figure 15(a) compares the speed tracking accuracy during decelerations with raw data (top left) and decelerations with three-cue flight director (top right). It is evident that speed errors were much smaller with the flight director and showed little evidence of the "fanning out" characteristic evident with raw data during the deceleration. The two bottom plots compare constant speed approaches for raw data (bottom left) with constant speed approaches with flight director (bottom right). Again, improvement is evident when flight director was used. When comparing accuracies between decelerating approaches and constant speed approaches, it can be seen that with the raw

data display, errors during constant speed approaches were smaller than those apparent during decelerations. This was not evident when using the flight director, where errors when performing constant speed approaches were similar to those during decelerations.

Figure 15(b) compares the azimuth (localizer) errors during decelerations with the raw data display (top left) with decelerations using flight director (top right). Again, improvement with flight director is evident. The two bottom plots represent errors during constant speed approaches using raw data (left) and flight director (right). Improvement with the flight director is again evident.

Figure 15(c) shows similar plots of height errors from the glideslope. These plots show none of the correlation evident with the previous two plots. When using raw data, comparison of errors between the decelerations (top left) and constant speed approaches (bottom left) show a slightly improved situation during constant speed approaches. On the other hand no apparent benefit is evident when using the collective flight director. Further study with a view to improving the collective flight director control laws is imperative before any conclusions regarding its usefulness can be made. Any improvement in this axis may allow the benefits of a flight directed display for decelerating approaches to be even more evident.

10.0 CONCLUSIONS

Based on a rather austere control system augmentation to the basic Bell 205A, i.e. rate damping augmentation in pitch, roll and yaw, the following conclusions can be made:

a) Decelerating approaches to 20 knots and constant speed approaches at 40 knots to Category IIIA weather minima could be flown with borderline Level 1 (certifiable) handling qualities with the aid of flight director guidance. However, in a colocated glideslope/helipad scenario, decision heights would have to be increased to 100 feet AGL for the constant speed approaches to allow sufficient deceleration distance.

b) Pilot workload and performance was similar for both the decelerating approaches and the constant speed approaches. However, workload was considerable in crosswind/shear conditions even when using a 3 cue flight director.

c) Approaches to Category II or Category IIIA minima without the use of a flight director were not certifiable for either constant speed approaches or decelerating approaches, especially during conditions of moderate turbulence and wind shear.

d) Attitude stabilization in pitch and roll provided marginal benefit during constant speed approaches and no significant benefit during decelerating approaches.

e) No conclusions could be formulated on the pilot workload and performance differences between a heading hold configuration and a turn coordination configuration due to a requirement to have a larger sample size in significant turbulence/wind shear atmospheric conditions.

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Mr. Eric Bries - FAA Southwest Region
Mr. James Erickson - FAA Southwest Region
Mr. Ken Mansfield - Transport Canada

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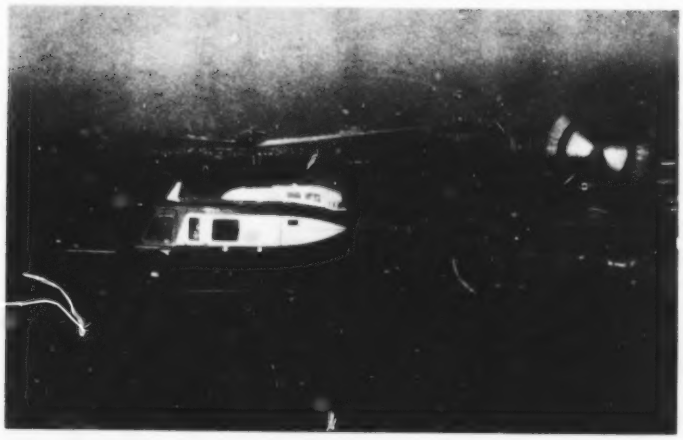


FIG. 1: THE NAE AIRBORNE SIMULATOR

FIG. 2: EVALUATION PILOT STATION

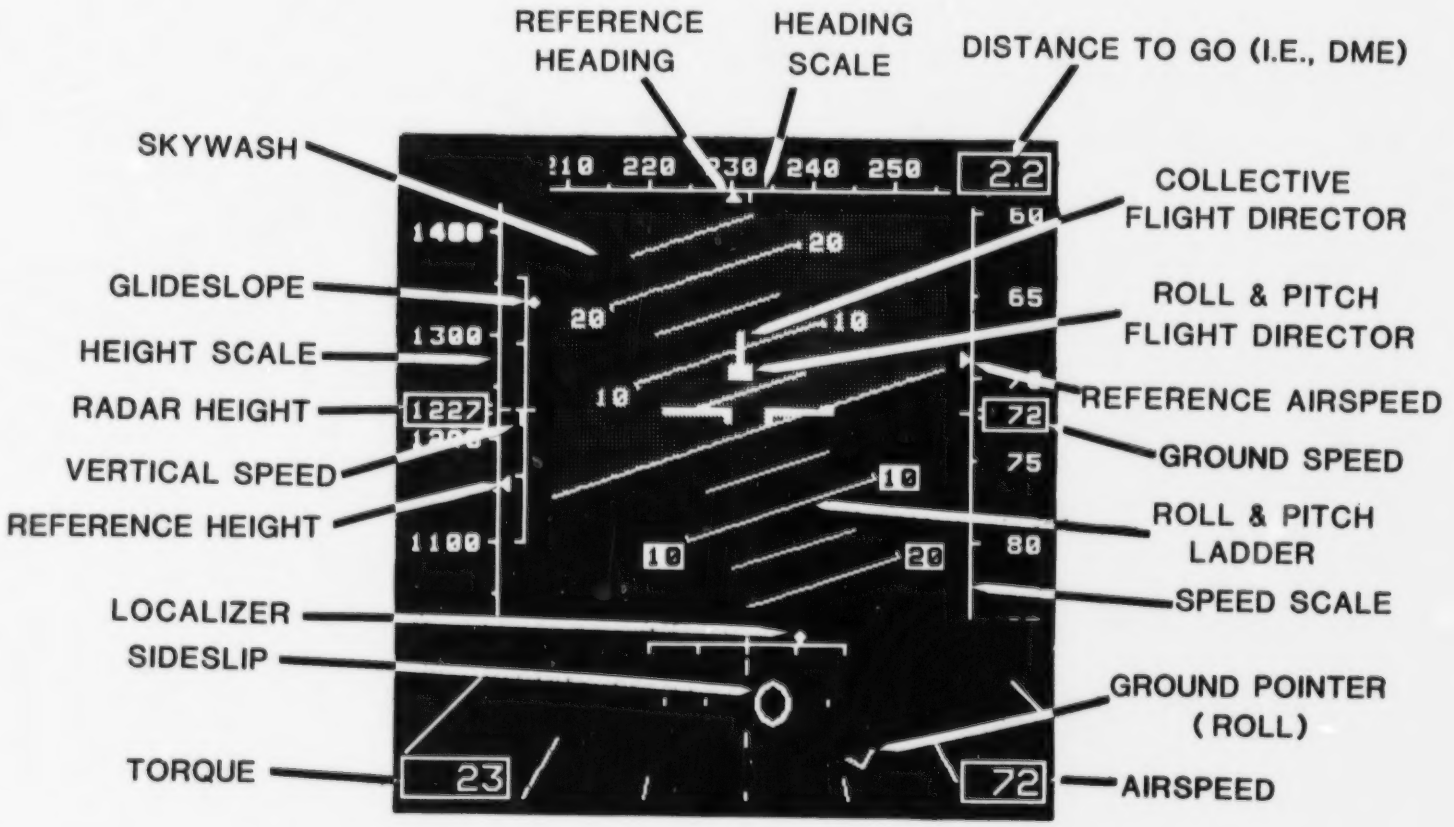
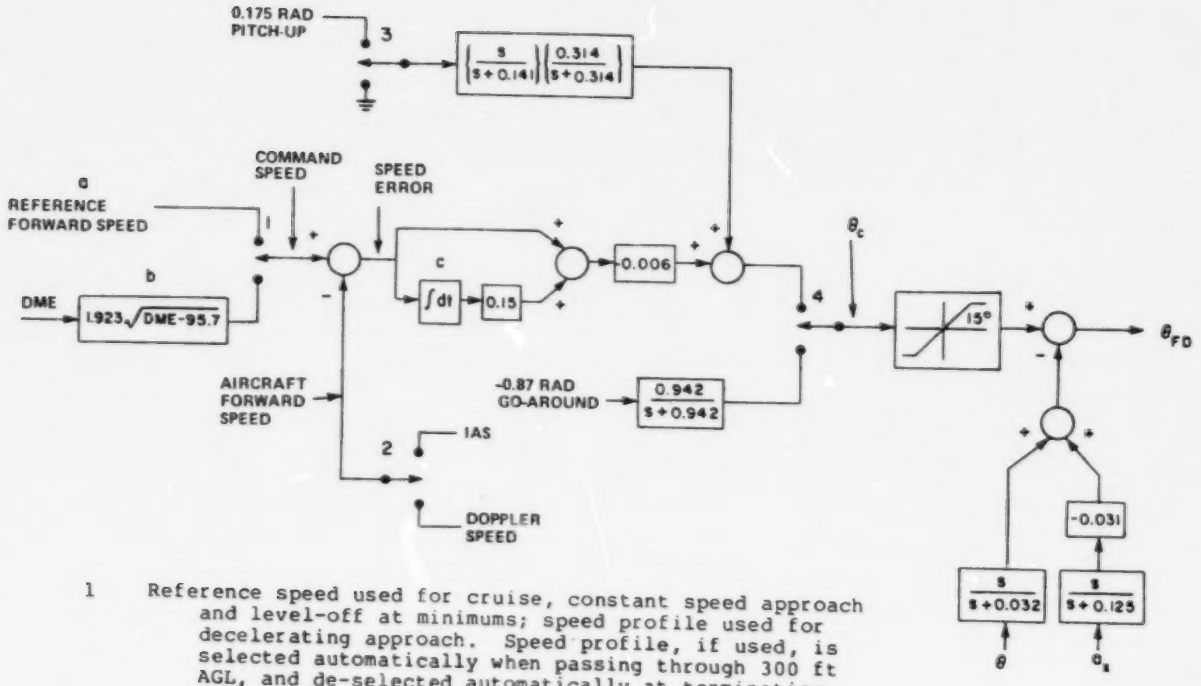


FIG. 3: PROGRAMMABLE, FLAT-PANEL ELECTRONIC DISPLAY

a Reference speed adjustable by pilot.

b Speed profile provides constant deceleration of 0.06g from 60 Kt to speed value occuring as aircraft passes through minimums.

c Integration active only for speed error less than ±5 Kt. Following de-activation, integration value is washed out with T = 10 sec.



1 Reference speed used for cruise, constant speed approach and level-off at minimums; speed profile used for decelerating approach. Speed profile, if used, is selected automatically when passing through 300 ft AGL, and de-selected automatically at termination of go-around manoeuvre.

2 Selection made manually by pilot, normally before commencement of approach.

3 Pitch-up selected automatically at 300 ft if conducting a decelerating approach.

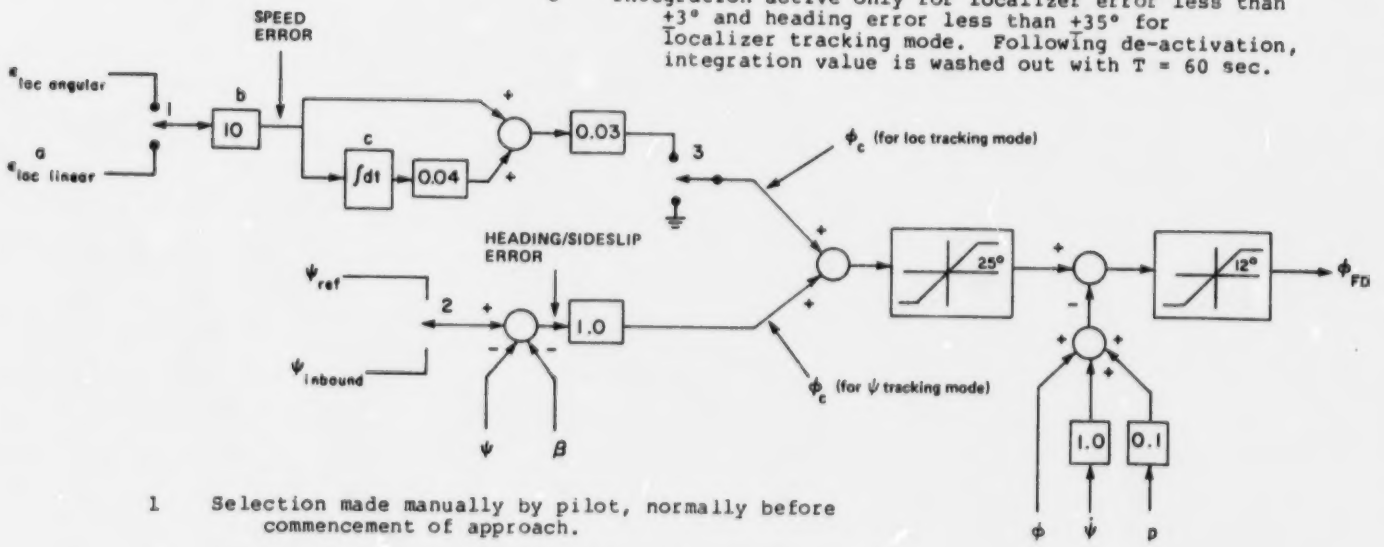
4 Go-around altitude commanded automatically upon selection of go-around mode by pilot.

FIG. 4: PITCH FLIGHT DIRECTOR

a Linearization of localizer signal, if used, takes effect only under 200 ft AGL.

b Gain is scheduled with DME, having full value (i.e., 10 fps/deg) before interception of glideslope and decreases linearly with DME to 20% of full value below 300 ft AGL.

c Integration active only for localizer error less than ±3° and heading error less than ±35° for localizer tracking mode. Following de-activation, integration value is washed out with T = 60 sec.



1 Selection made manually by pilot, normally before commencement of approach.

2 Inbound heading selected automatically when localizer error decreases below ±3°, and de-selected automatically when localizer error increases above ±5.5°.

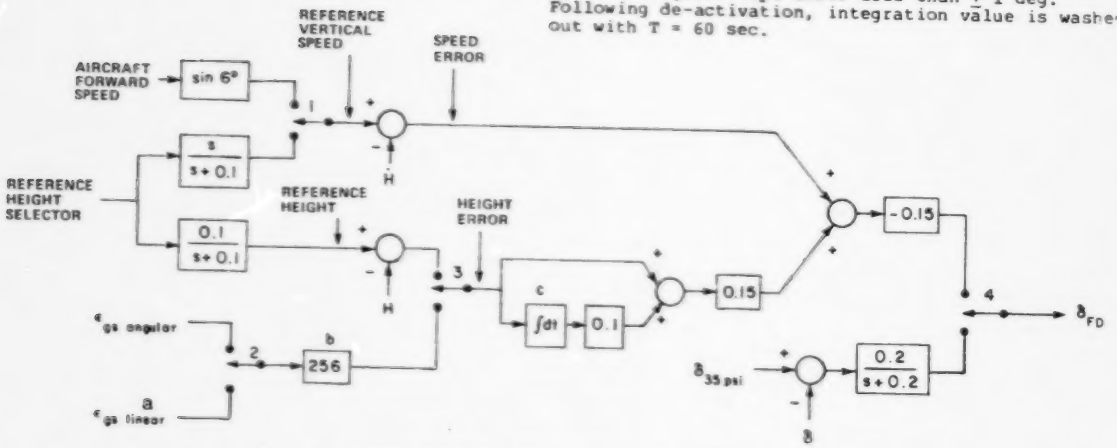
3 Localizer path selected/de-selected automatically under same conditions as above.

FIG. 5: ROLL FLIGHT DIRECTOR

a Linearization of glideslope signal, if used, takes effect only under 200 ft AGL.

b Gain is scheduled with DME, having full value (i.e., 256 ft/deg) before interception of glideslope and decreasing linearly with DME to 20% of full value below 300 ft AGL.

c Integration active only for height error less than ±100 ft or glideslope error less than ± 1 deg. Following de-activation, integration value is washed out with T = 60 sec.



1 Reference vertical speed derived from high-pass of reference height selector for cruise and level-off at minimums; derived from aircraft forward speed for approach. Approach mode selected automatically when glideslope error decreases below +0.25° and de-selected automatically when glideslope error increases above ±1.8° or upon reaching minimums.

2 Selection made manually by pilot, normally before commencement of approach.

3 Glideslope path selected automatically when glideslope error decreases below +0.1 and de-selected automatically when glideslope error increases above ±1.8°.

4 Climb-out power equivalent of 35 psi torque commanded automatically upon selection of go-around mode by pilot.

FIG. 6: COLLECTIVE FLIGHT DIRECTOR

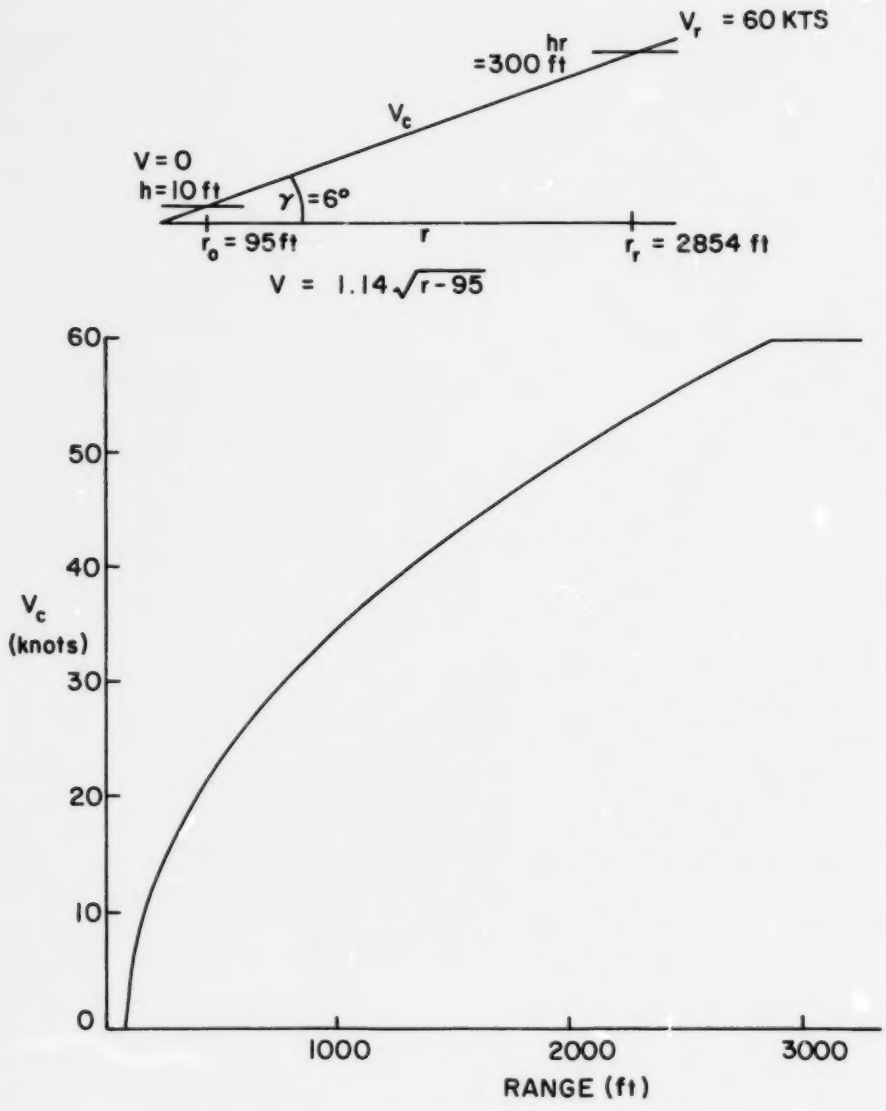


FIG. 7: SPEED DECELERATION PROFILE

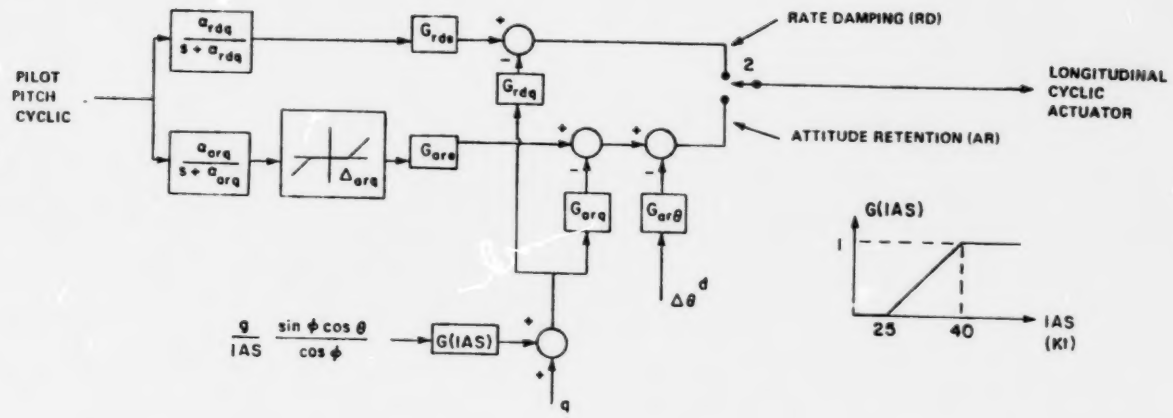


FIG. 8(a): LONGITUDINAL RATE DAMPING/ATTITUDE RETENTION

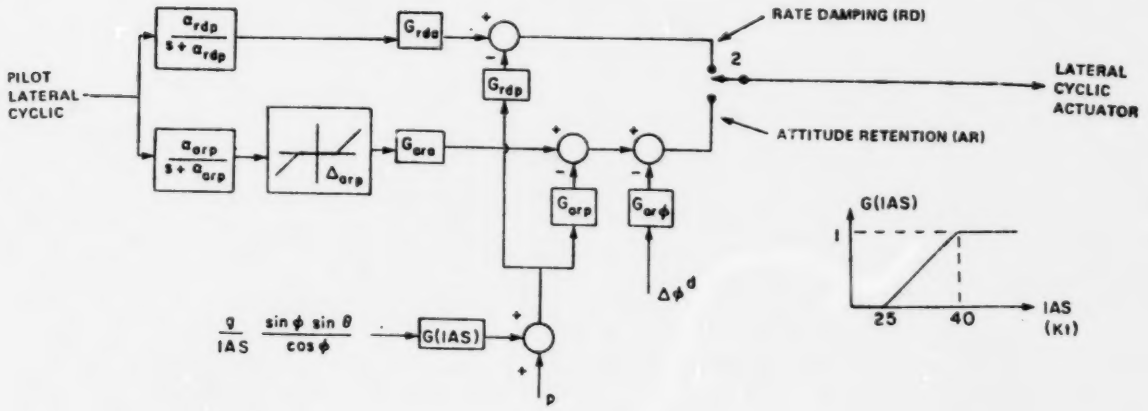


FIG. 8(b): LATERAL RATE DAMPING/ATTITUDE RETENTION

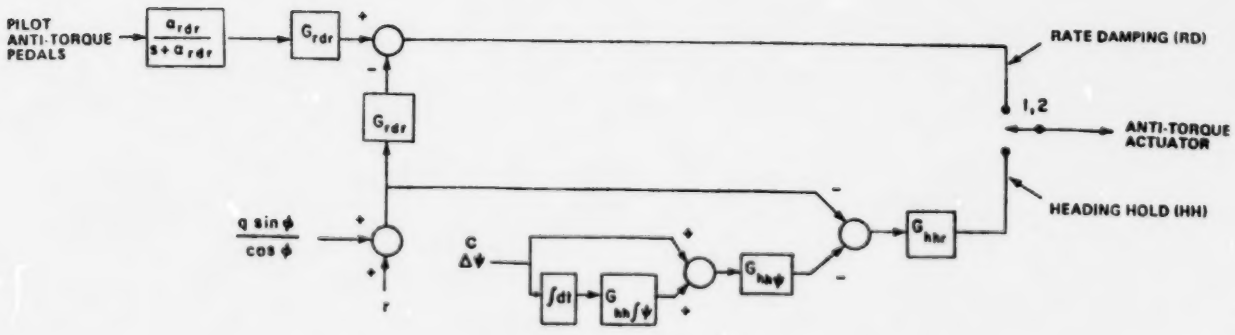


FIG. 8(c): YAW DAMPING/HEADING HOLD

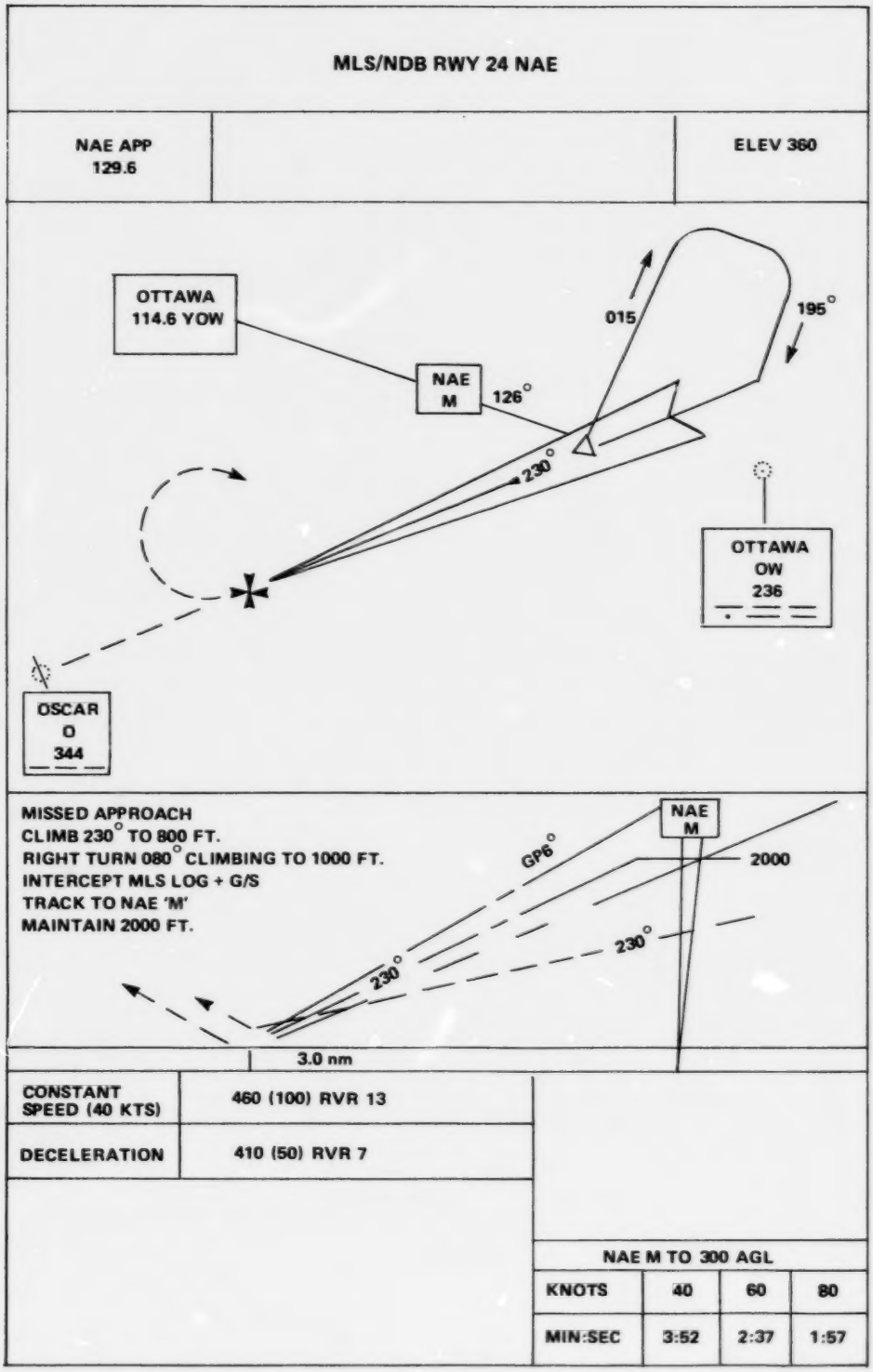


FIG. 9: MLS APPROACH PLATE

EVALUATION PILOT: _____ MODEL NO.: _____

FLIGHT NO. AND DATE: _____ RECORDER RUN NO.: _____

WINDS AND TURB.: _____ DECISION HEIGHT: _____

BREAKOUT: YES NO

---

1. a. Most difficult phase? _____

   b. Cooper-Harper rating

2. Comments on distinguishing characteristics or features:

   a. Prior to deceleration point:

      i. Azimuth Control

      ii. Elevation Control

      iii. Speed Control

      iv. General Comments

   b. During deceleration:

      i. Azimuth Control

      ii. Elevation Control

      iii. Speed Control

      iv. General Comments

3. IFR certification level (see extended description of categories):

   a. Good 1-Pilot

      Marginal 1-Pilot

      2-Pilot

      Non-certifiable

   b. Comments:

FIG. 10: APPROACH QUESTIONNAIRE

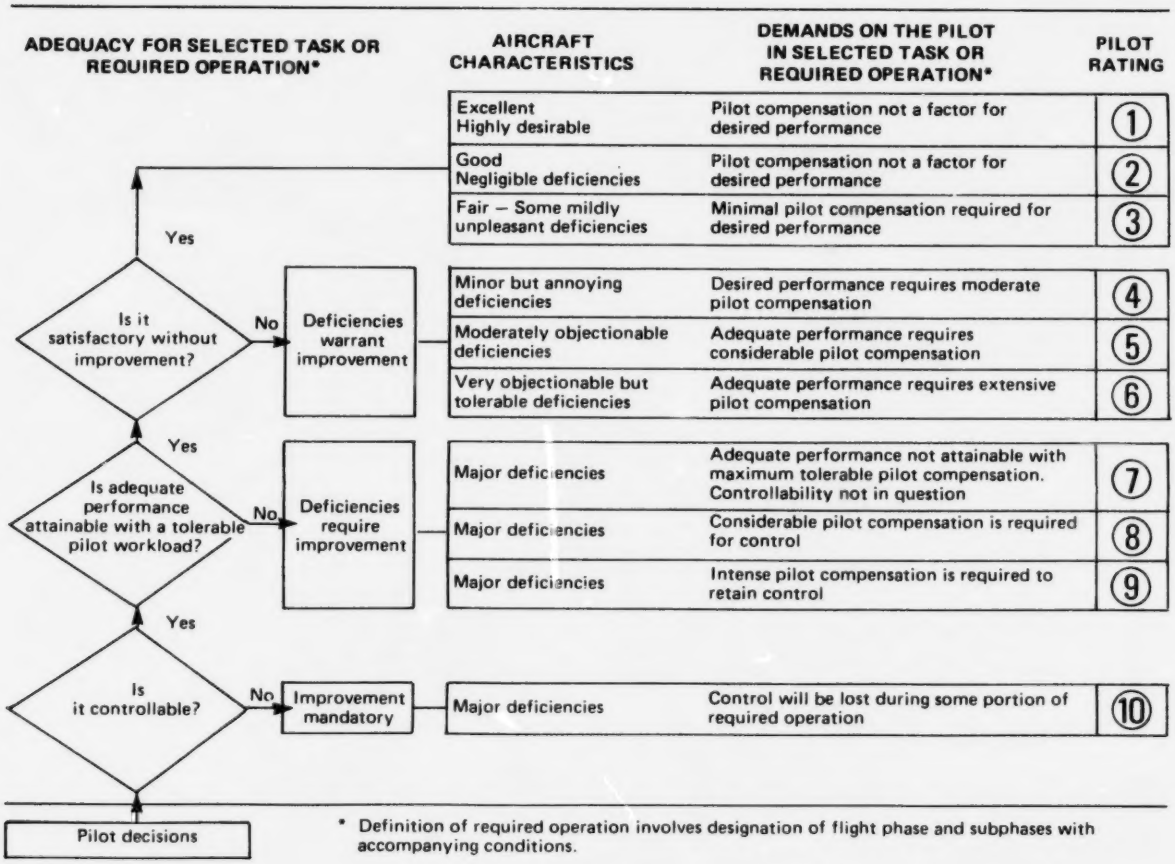

ADEQUACY FOR SELECTED TASK OR REQUIRED OPERATION*
AIRCRAFT CHARACTERISTICS
DEMANDS ON THE PILOT IN SELECTED TASK OR REQUIRED OPERATION*
PILOT RATING
Excellent Highly desirable
Pilot compensation not a factor for desired performance
1
Good Negligible deficiencies
Pilot compensation not a factor for desired performance
2
Fair – Some mildly unpleasant deficiencies
Minimal pilot compensation required for desired performance
3
Yes
Is it satisfactory without improvement?
No
Deficiencies warrant improvement
Minor but annoying deficiencies
Desired performance requires moderate pilot compensation
4
Moderately objectionable deficiencies
Adequate performance requires considerable pilot compensation
5
Very objectionable but tolerable deficiencies
Adequate performance requires extensive pilot compensation
6
Yes
Is adequate performance attainable with a tolerable pilot workload?
No
Deficiencies require improvement
Major deficiencies
Adequate performance not attainable with maximum tolerable pilot compensation. Controllability not in question
7
Major deficiencies
Considerable pilot compensation is required for control
8
Major deficiencies
Intense pilot compensation is required to retain control
9
Yes
Is it controllable?
No
Improvement mandatory
Major deficiencies
Control will be lost during some portion of required operation
10
Pilot decisions
* Definition of required operation involves designation of flight phase and subphases with accompanying conditions.

FIG. 11(a): HANDLING QUALITIES RATING SCALE

BASED ON YOUR SHORT EVALUATION, IN WHICH OF THE FOLLOWING CATEGORIES WOULD YOU PLACE THIS CONFIGURATION:

1. The helicopter has good flying qualities and could be operated safely in a high-density IFR environment by one pilot without the assistance of additional crew members. ☐

2. The helicopter has marginal flying qualities for operations in a high-density IFR environment by one pilot without the assistance of additional crew members. ☐

3. The helicopter has flying qualities deficiencies which make it unsuitable for single-pilot operations in a high-density IFR environment, however it could be operated safely within such an environment if the pilot-in-command were relieved of all non-control tasks by an additional qualified crew member. ☐

4. The helicopter has major flying qualities deficiencies which make it unsuitable for operation within a high-density IFR environment. ☐

FIG. 11(b): CERTIFICATION RELATED ASSESSMENT

	PILOT A	PILOT B	PILOT C	PILOT D
TOTAL FLIGHT TIME	3,600	11,300	3,500	5,270
TOTAL HELICOPTER	2,300	2,680	2,500	825
TOTAL INSTRUMENT	500	5,650	400	770

FIG. 12: EVALUATOR PILOTS' EXPERIENCE SUMMARY

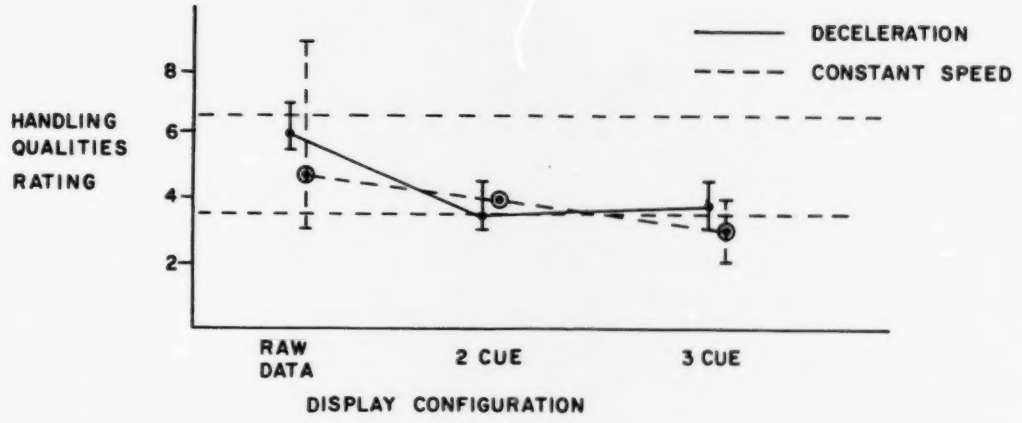


FIG. 13(a): HANDLING QUALITIES RATINGS
THREE-AXIS RATE DAMPING – NO ATTITUDE STABILIZATION

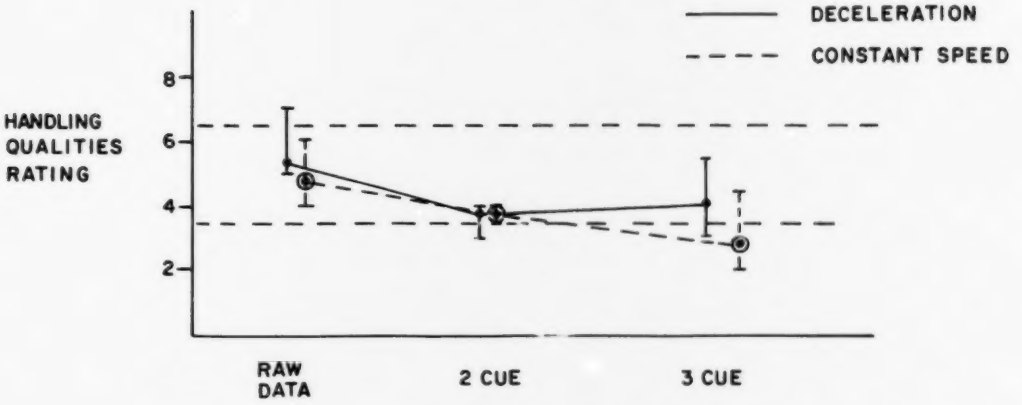


FIG. 13(b): COMPARISONS IN SMOOTH CONDITIONS –
ALL SAS CONFIGURATIONS

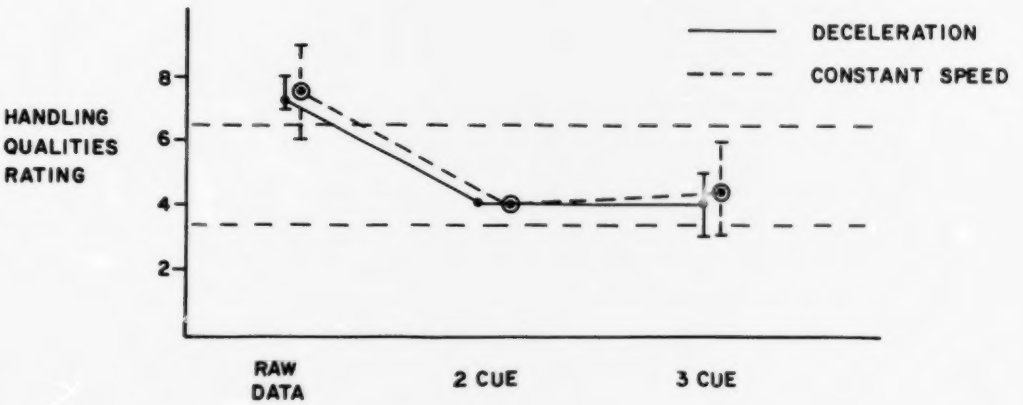


FIG. 13(c): COMPARISONS IN MODERATE WIND SHEAR
AND TURBULENCE – ALL SAS CONFIGURATIONS

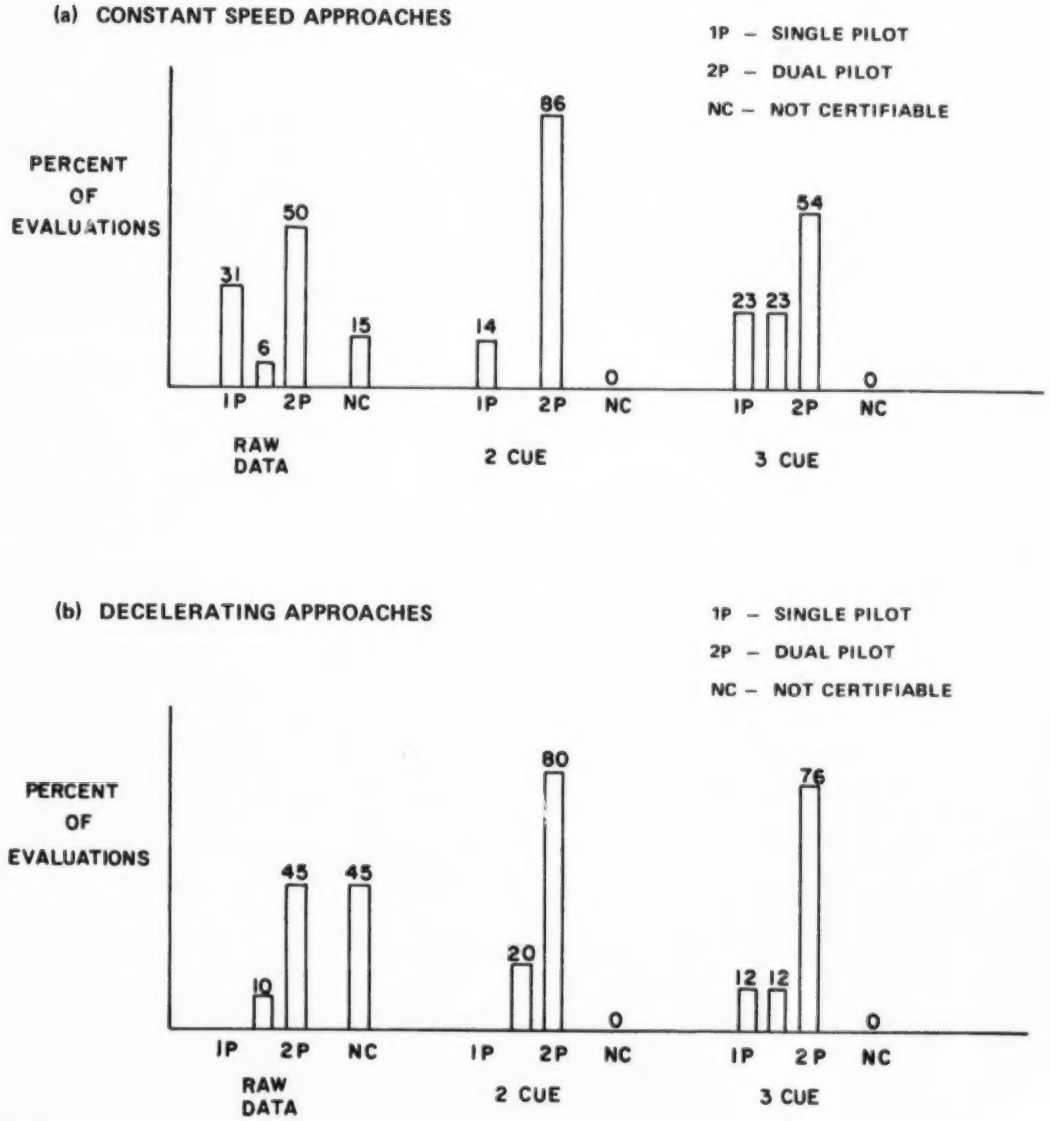
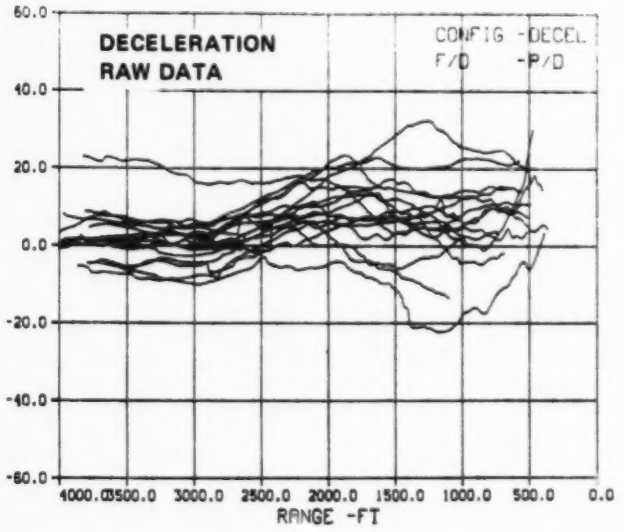
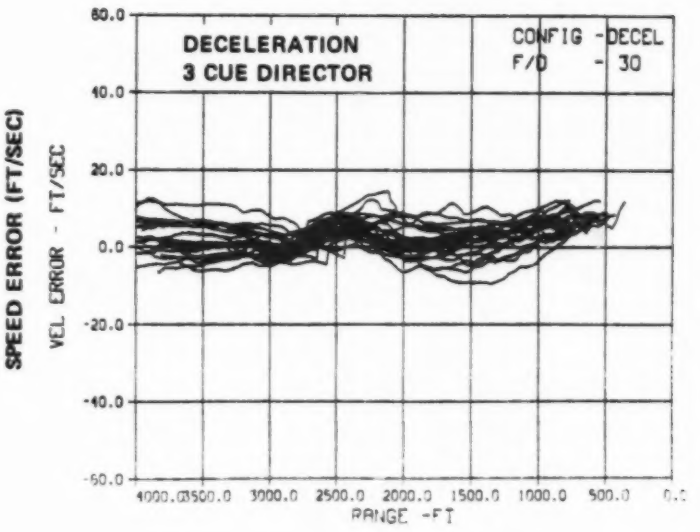
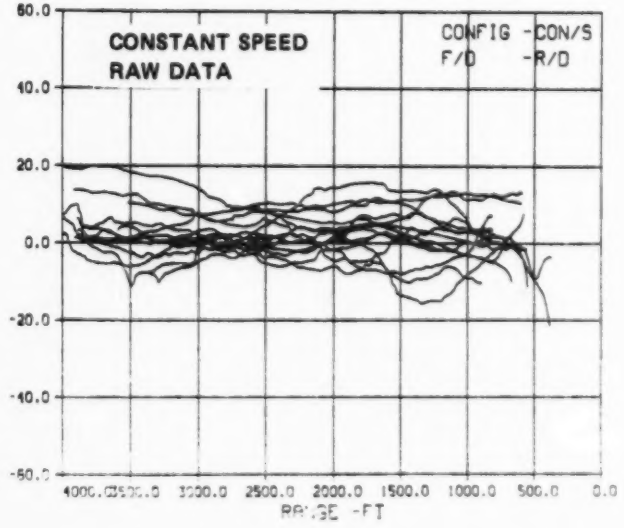


FIG. 14: CERTIFICATION ASSESSMENTS –
ALL SAS CONFIGURATIONS
ALL ATMOSPHERIC CONDITIONS







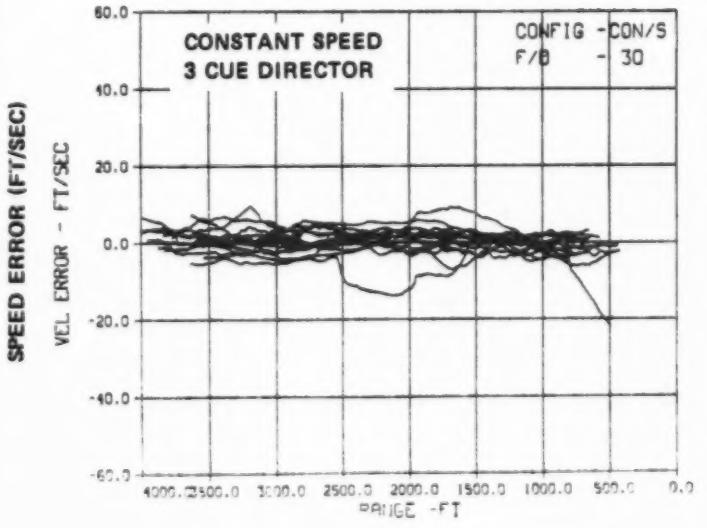
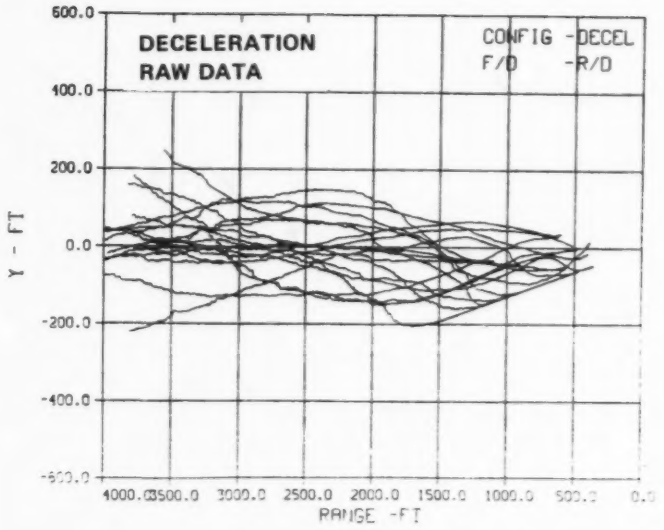
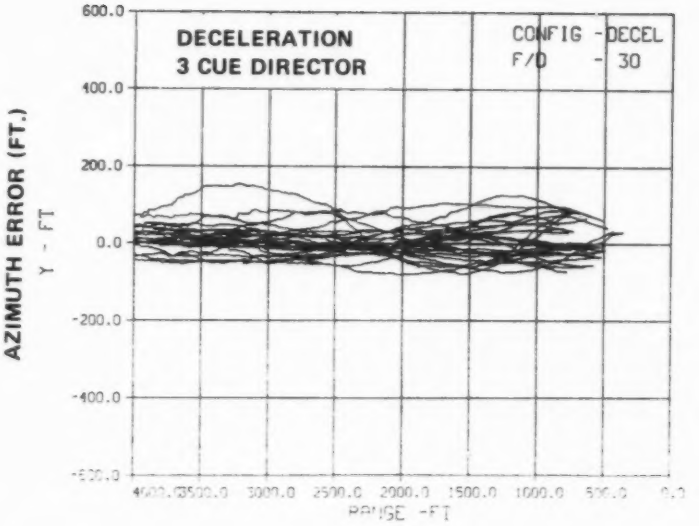
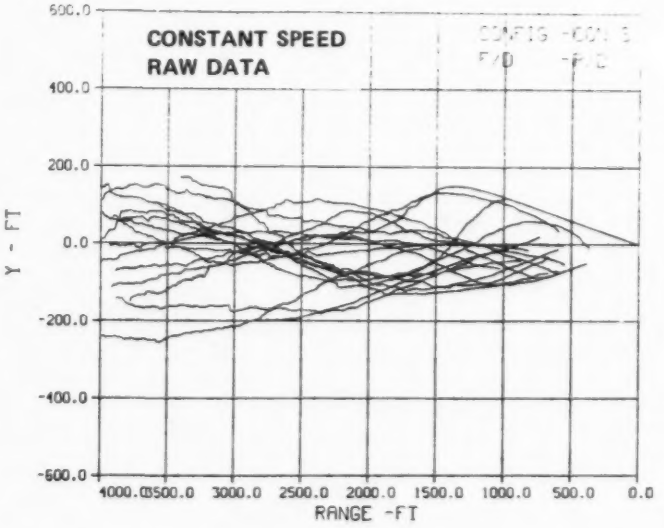


FIG. 15(a) SPEED TRACKING PERFORMANCE







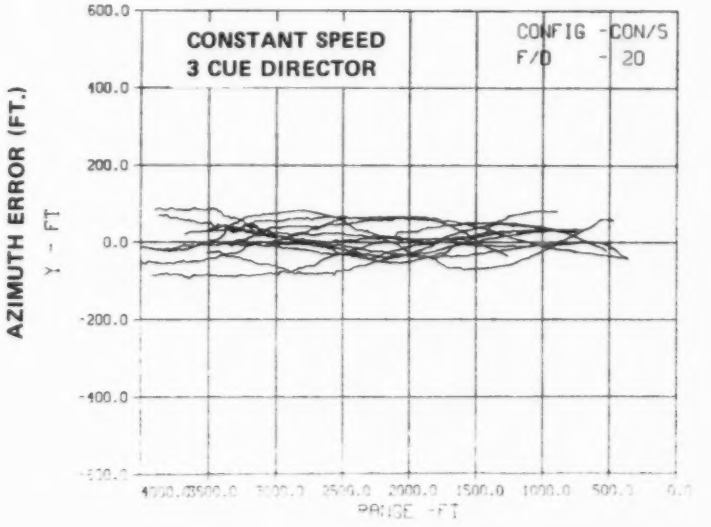


FIG. 15(b): AZIMUTH TRACKING PERFORMANCE

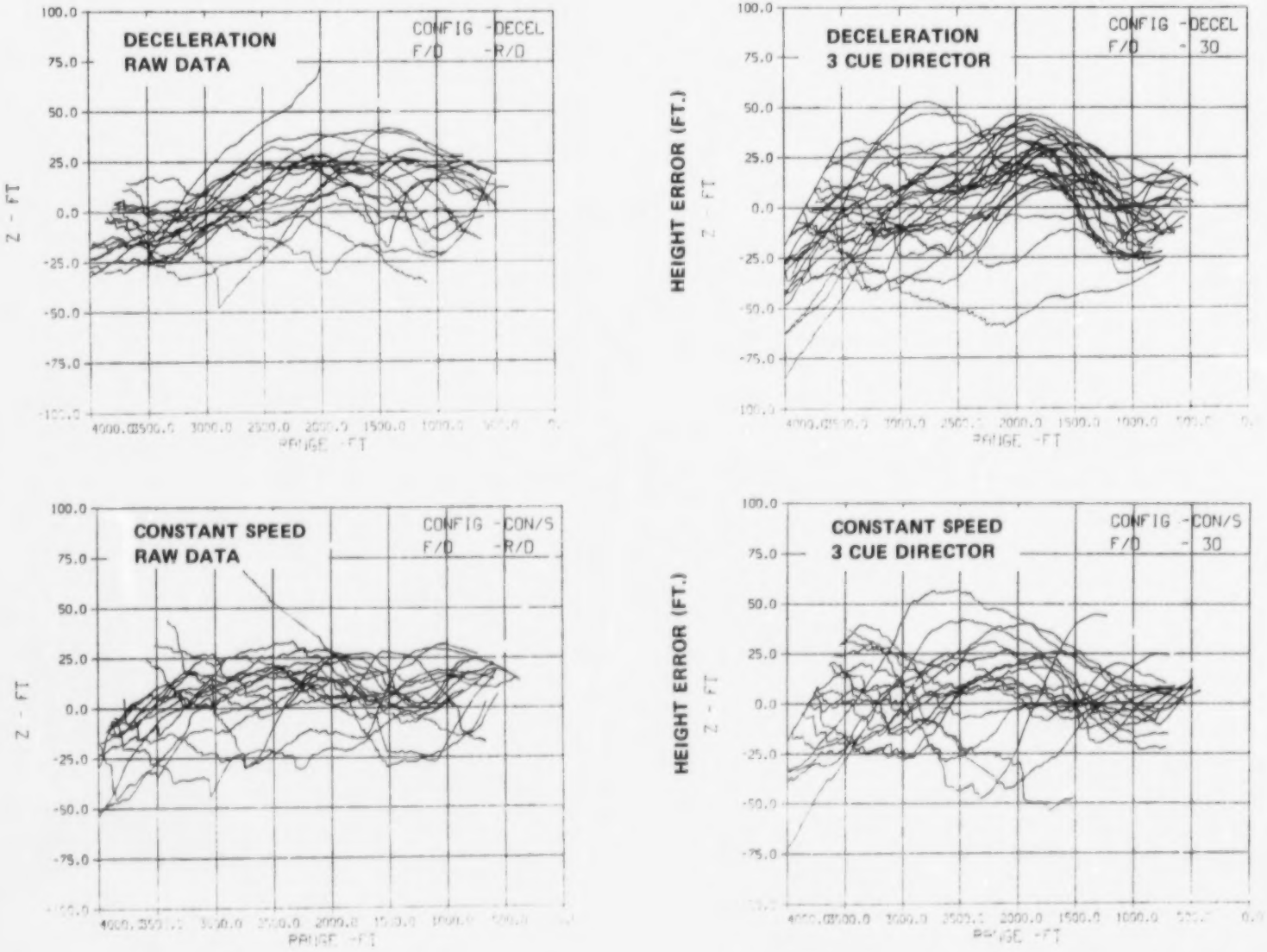


FIG. 15(c): HEIGHT TRACKING PERFORMANCE

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Determination of Handling Qualities and Display Requirements for Helicopter Instrument Flight During Decelerating Approaches to Slow Speeds

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1. Helicopters — handling
2. Instrument flight
3. Deceleration — instrumentation

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This paper discusses the most recent phase of a series of experiments performed jointly by the National Aeronautical Establishment and the United States Federal Aviation Administration under Memorandum of Agreement AIA-CA-31. The experiment was aimed at determining the helicopter instrument flight handling qualities requirements when performing steep approaches to low decision heights to a landing area colocated with a Microwave Landing System (MLS).

A total of 118 approaches were evaluated by three helicopter certification test pilots and one operational/training helicopter pilot. Results indicate that with simple rate damping augmentation in pitch, roll and yaw, and flight director guidance, a Bell 205A-1 exhibited borderline Level 1 (certifiable) handling qualities when performing decelerating approaches to 20 knots to decision heights representative of Category IIIA weather limits.